

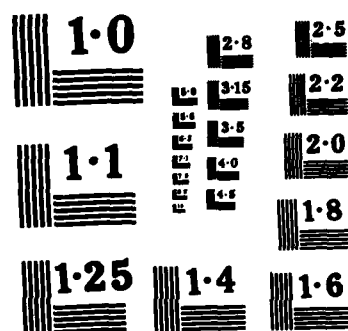
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INVESTIGATION OF ICE DYNAMICS IN THE MARGINAL ICE ZONE

Principal Investigator: Dr. Matti Leppäranta
Contractor: Institute of Marine Research, Finland
Contract Number: DAJA45-83-C-0034
Interim Technical Report
1 September 1984 - 15 May 1985

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Interim Technical Report

Investigation of Ice Dynamics in the Marginal Ice Zone

Dr. Matti Leppäranta

1. General

The entitled work was commenced by the author on January 24, 1983, at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH, and is done in cooperation with Dr. William D. Hibler III from CRREL. Since March 1984 the author has continued this research at the Finnish Institute of Marine Research. The work includes both a theoretical and an experimental part. This year most of it is involved with processing the data of MIZEX-83 and MIZEX-84 experiments in the Greenland Sea. The field work has been discussed in earlier reports.

Dr. Hibler is now spending a sabbatical year at Max-Planck-Institut für Meteorologie, Hamburg, and so it is easy for us to meet when necessary. In this year we have so far met on two occasions discussing mainly on MIZEX-83 data and modeling problems.

This research project has already been partially producing six publications in MIZEX Bulletin (Hibler and Leppäranta, 1984; Hibler et al., 1984; Leppäranta, 1984; Leppäranta and Hibler, 1984 a; Leppäranta and Hibler, 1984 b; Sten et al., 1984). Two copies of each of them are enclosed in a separate package.

2. MIZEX-83

MIZEX-83 was a pilot study program where ice kinematics data could be collected for about ten days, (see Fourth Interim Report). Ocean current measurements were simultaneously made by the University of Bergen, and they had three stations in the same ice floes as we had transponders for the ice kinematics study, (Fig.1).

The currents were measured with Aanderaa current recorders giving the mean absolute speed and instantaneous direction at ten-minute intervals. The measurement depths were 2, 10, 20, 40 and 200 meters beneath the ice bottom. Since our ice kinematics

data describe relative motion between the stations, we must consider relative motion also in the ocean, i.e., spatial fluctuations of velocity between two stations and the rate of deformation given by the three stations. This work is still going on and preliminary results indicate several important conclusions.

The most important conclusion is that spatial variations in the current velocity are on average nearly an order of magnitude larger than spatial variations in the ice velocity. This means that the ice is not a passive tracer of ocean current structure but has an active role in damping velocity variations. The cause of this damping effect is the internal friction in the ice floe system, i.e. interaction between ice floes. The role of this ice interaction has not yet been well understood or accepted by a number of scientists working on polar ocean problems. In particular, it has been argued that in the marginal ice zone, where the open ocean boundary is nearby, the ice should drift free of internal stresses. MIZEX-83 combined ice motion and current observations are maybe the best data set so far to show the importance of internal friction within the ice in the marginal ice zone.

The active role of ice in the ice - ocean system has a consequence that an ocean dynamics model for the ice margin problems should have an advanced ice dynamics model coupled with it. Such modeling work has not yet been done.

As the last point, it has become clear that when ocean currents are measured from ice floes, the motion of the floes themselves must be measured very accurately. This is especially true as one tries to observe the differential current field. For frequencies up to about two cycles per hour our microwave tranponder system is accurate enough giving distances between stations up to ± 1 m. On the other hand, it seems that there is not much use of Argos satellite buoys in measuring differential kinematics in the mesoscale.

(continued)
3. MIZEX-84

L → MIZEX-84 was the main summer experiment of the MIZEX program (Johannessen et al., 1983). Ice kinematics data was there collected for forty days from R/V Polarqueen, which was the main drifting station.

station. The field work was described in the Fifth Interim Report.

Fig. 2 presents an overall chart of data taken and is organized by transponder unit number. In the table, RL refers to a "range loop" measurement which is needed to triangulate the location of the corresponding unit relative to the master station in Polarqueen. Without the range loop measurement one gets only the direct distance between master and the unit. Gaps (other than occasional) in the data outputs are indicated but not annotated with details (bears, deformation out of range, etc.).

A basic processing of the data was done by Keith Alverson at CRREL in the fall 1984. This consisted of a general inspection of the data, transferring them from Apple II computer discettes to the Prime computer at CRREL, and constructing suitable files for further processing. These files were then sent to Finland in magnetic tape at the end of 1984.

There has been some problems in MIZEX-84 data concerning calibration factors of the distance measurements by the microwave transponder system. This is presently being worked on and has to be done manually.

Basically, it is intended to carry through the analysis of MIZEX-83 data before doing the heavy computer work with MIZEX-84 data. A large part of MIZEX-84 data processing can be made with the computer programs already written for processing MIZEX-83 data.

4. Modeling

A final manuscript was prepared of one-dimensional modeling studies of ice drift in the marginal ice zone. This work was done earlier by Dr. Hibler and the author at CRREL and the preliminary results have been described in the Second Interim Report (see also Leppäranta and Hibler, 1984 b). The manuscript was sent to Journal of Geophysical Research late 1984 and was revised according to comments of two reviews this spring.

The one-dimensional model is a special application of Hibler's (1979) general model to the marginal ice zone. The ice is assumed to behave as a viscous plastic material and its drift is affected by wind stress, water stress and the Coriolis effect. It has been shown by the model simulations that the nonlinear plastic nature of ice interaction and the nonlinear coupling

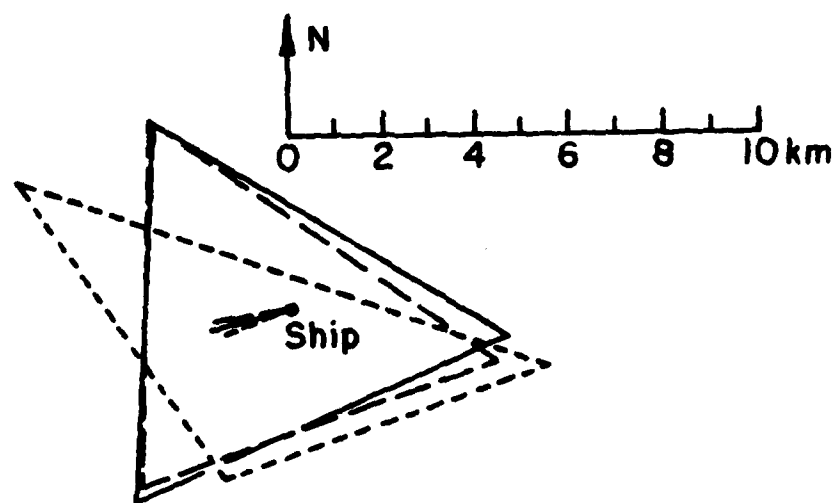
between ice thickness characteristics and ice rheology can substantially modify the character of marginal ice zone dynamics.

For constant forcing the steady state solution of ice drift in the marginal ice zone has four different categories (Fig.3). Off-ice forcing diffuses the ice pack whereas for nearly on-ice forcing the ice motion eventually comes to stop. For a significant component both on-ice and along ice edge, a steady drifting marginal ice zone is possible. In these cases the ice drift is directed in the direction of the ice edge and the speed is less than the theoretical free drift speed (i.e. ignoring ice interaction).

For spatially variable forcing the ice drift very slowly approaches the forcing distribution. This adjustment is so slow that forcing variations are in practice effectively damped. Thus our modeling studies do not support the occurrence of a jet near the ice edge as a steady state phenomenon. Such possibility has been discussed much in the literature but not clearly found from observations. A transient jet is, however, possible in the light of these modeling studies.

5. References

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- 29 Jun (0800 GMT)
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- 8 Jul (0800 GMT)



Open Water

Fig. 1. Configuration change of the triangle over the period of MIZEX-83 experiment. Transponders and Aanderaa current recorders were located in the same floe at the vertexes of the triangle. Also shown is the approximate location of the ice edge drawn to scale.

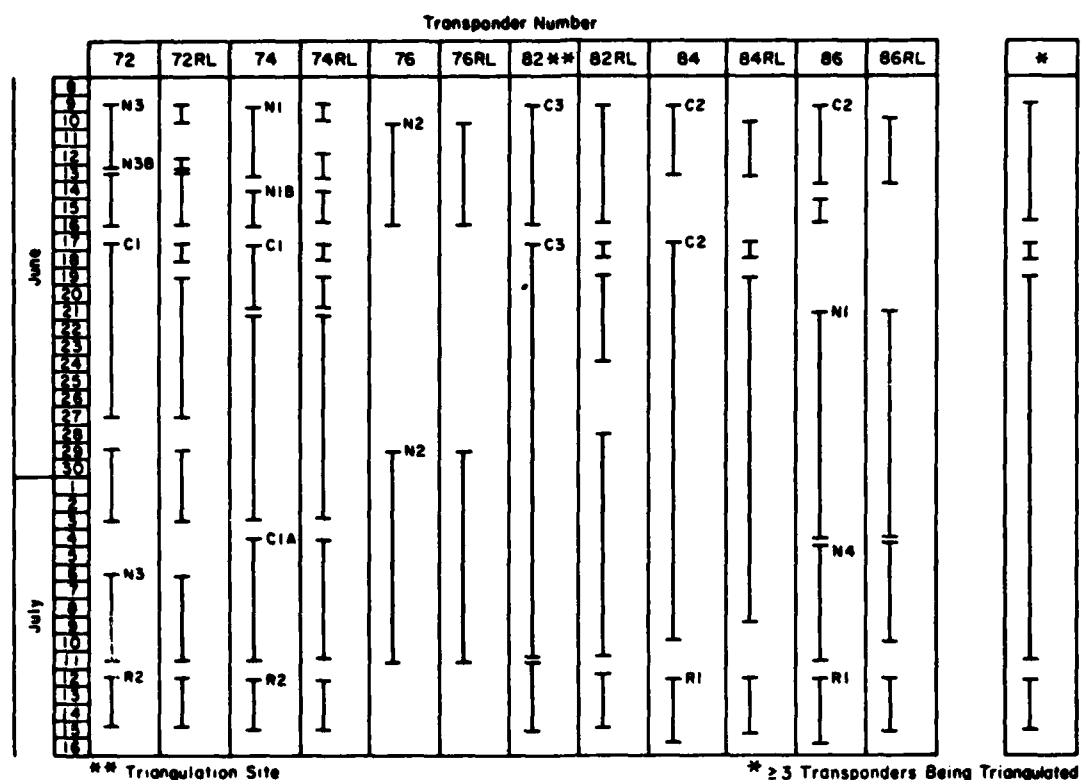


Figure 2. Deployment chart for transponders. The chart shows times when direct measurements and range loop measurements (denoted by RL) were made at 15-min intervals to transponder unit numbers 72, 74, 76 and 82, 84, 86. For range loop measurements, a slave unit was located at site 82. (The range loop measurement to 82 is redundant as it effectively gives an additional but unneeded distance measurement to unit 82 from the ship.)

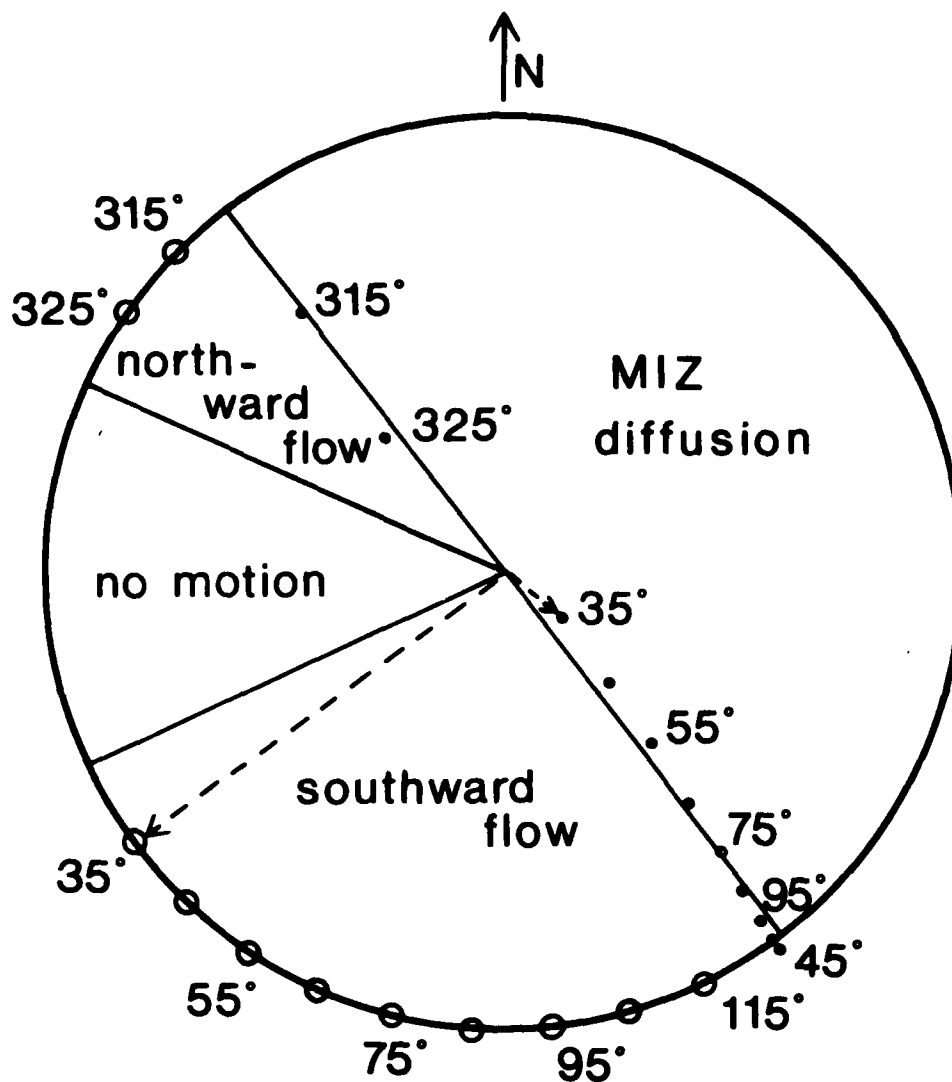


Fig. 3. The motion of the marginal ice zone after adjustment between ice mass and velocity. The wind speed is spatially and temporally constant. The ice edge is oriented north-south and the large circle indicates the wind stress vectors from the center point to different directions. For edge-parallel flows, open circles show the wind stress on the ice and filled circles show the stress into the ocean; the 35° case stress vectors are shown as an example.

ANNEX

a. The amount of unused funds: none

b. Important property required: none

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